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(54) METHOD FOR PRODUCING A COATING MADE OF POWDERED MATERIALS AND DEVICE FOR REALISING THE SAME

(57) The present invention relates to the field of producing coatings and may be used in metallurgy, in mechanical engineering, in radio- and electronic engineering. The essence of the invention is that for broadening th technological possibilities of producing a coating from various powder materials, for increasing the effectiveness of the process of applying and forming a coating, and for prolonging the service life of the spraying system, as well as for improving the physicochemical properties of the produced coating, in a method comprising the steps of forming an accelerating flow of a working carrier gas, introducing particles of a powder material thereinto, feeding the resulting gas-and-powder mixture into an accelerating supersonic nozzle and applying the powder material to the surface of an article by means of the gas flow, before feeding the gas-and-powder mixture into the accelerating nozzle (16), this mixture is preliminarily accelerated by a gas, which is in rt to the starting material, to a velocity defined by the Mach number within $0.3 \leq M \leq 1.0$, and then an additional acceleration is carried out, for which purpose the gas-and-powder mixture is introduced into the core of the accelerating flow of the working carrier gas. Before applying the powder material to the surface to be coated, the powder particles are separated from the gas by changing the direction of the gas flow. For carrying the method into effect, in a device comprising a spraying unit made in the form of an accelerating supersonic nozzle (16) and an intermediate nozzle (13); a means (9) for feeding the working carrier gas; a means for introducing the gas-and-powder mixture; and a metering feeder (6); provision is made for a means for feeding additional gas inert to the powder material; for the intermediate nozzle (13) to be made as a supersonic one, with the diameter of the nozzle exit section $d_{sect.}$ smaller than the diameter of the critical section $D_{crit.}$ of the accelerating nozzle, and for arranging the nozzle (13) coaxially with the nozzle (16) in the subsonic part of the latter, with the possibility of translational displacement. For varying the direction of the gas flow, the accelerating supersonic nozzle (16) has at the outlet of its supersonic part a linear portion (17) which passes into a portion with a curvilinear surface (18) of a radius R.

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Description

T chnical Field

[0001] The present invention relates to the field of applying and producing coatings from powder materials and more particularly to a method of producing a coating from powder materials and to a device for carrying out said method.

Background of the Invention

[0002] Known in the art is a method of producing a coating from powder materials, which comprises introducing a starting powder material into a gas stream which accelerates material particles, shaping a high-velocity gas-and-powder jet, and applying the powder mat rial to the surface of an article (Inventor's Certificate RU No. 1618778, Cl. C23C 4/00, 1991).

[0003] This method suffers from the following disadvantages: particles of a coating material cannot be accelerated by a gas stream up to velocities close to those of the gas accelerating thereof, and the process of forming a coating cannot be effected with relatively not high parameters of the working gas (air) with the pressure P $< 10^{*}10^{5}$ N/m^2.

[0004] Said disadvantages restrict the technological possibilities of the method and involve considerable pow r inputs.

[0005] Also known in the art is a method of producing a coating from powder materials on the surface of an article whose material is selected from the group consisting of metals, alloys, dielectrics, which method comprises the steps of forming an accelerating flow of a working carrier gas, introducing particles of a powder material into this flow, feeding the resulting gas-and-powder mixture into an accelerating supersonic nozzle, and applying the powder material to the surface of an article by the gas flow (International Application WO 91/19016, Cl.. C23C 4/00, B05B 7/24, B05C 19/00, 1991).

[0006] For carrying this method into effect, a device is used, comprising a spraying unit made as a supersonic nozzle with a subsonic converging and a supersonic parts and an intermediate nozzle, a means for fe ding a compressed working carrier gas, and a means for introducing a gas-and-powder mixture into the spraying unit (International Application WO 91/19016, Cl. C23C 4/00, B05B 7/24, B05C 19/00, 1991).

[0007] The disadvantages of the known method and device are as follows: limited possibilities of producing an adequate-quality coating material due to the presence of a superficial oxide film on particles of the employed powder materials and, as a result, the presence of oxides in the structure of the coating material; an insufficient effectiveness of the particle acceleration process due to the deceleration of particles in the compressed wall layer of gas at the surface of the article being treated; insufficiently high physicochemical properties of produced coatings; limited possibilities of controlling the velocity of the gas flow and the particles of the powder material from which the coating is formed; the presence of friction and of the deceleration of particles along the walls of the acceleration channel of the supersonic nozzle, which lead to reducing the effectiveness of the coating application process and the service life of the spraying system. Said disadvantages interfere with producing coatings having high physico-mechanical properties, restrict the technological possibilities of producing a high-quality coating from powder materials, and also interfere with the provision of a high effectiveness of the coating application process and with the provision of a long service life of the spraying system.

Disclosure of the Invention

[0008] The problem underlying the described invention is the provision of a method of preparing a coating from powder material and a device for carrying this method into effect, which would make it possible to broaden the technological possibilities of producing coatings from various powder materials and from their mixtures, to improve the physicochemical properties of the resulting coating material, to raise the effectiveness of the process of applying and forming the coating, and to prolong the service life of the spraying system.

[0009] The indicated technical result is attained owing to the use of method of producing a coating from powder materials and of a device for carrying this method into effect, the essence of which is as follows:

[0010] The herein-proposed method of producing a coating from powder materials, comprising the steps of forming an accelerating flow of a carrier gas, introducing particles of a powder material thereinto, feeding the resulting gas-and-powder mixture into an accelerating supersonic nozzle, and applying the powder material by means of the gas flow to the surface of an article, envisages that before feeding the gas-and-powder mixture into the supersonic nozzle the mixture is pre-accelerated by a gas inert with respect to the starting powder material to a velocity defined by the number $0.3 \leq M \leq 1.0$, where M is the Mach number, and accelerated additionally by introducing the gas-and-powder mixture into the core of the accelerating flow of the carrier gas, and that before applying the coating powder material to the surface of an article the powder particles are separated from the gas. The accelerating flow of the working carrier gas is formed in accordance with the square law of variation of the profile of the accelerating supersonic nozzle area. This provides a possibility for a more effective utilization of the gas flow energy.

[0011] It is reasonable to effect feeding of th gas-and-powder mixture into th accelerating nozzle with the cumulative flow of the accelerating carrier gas and of the gas inert to the powder material set in accordance with the rated conditions of the accelerating nozzle.

[0012] The m thod envisages the use of air or of a mixture of gases as the working carrier gas and the use of a gas or a mixture of gases not reacting with the powdered components of the powder material as the gas inert with respect to this material.

[0013] Before the preliminary acceleration of the powder material, it is subjected to mechanical, electrochemical or chemical treatment in a gaseous medium inert to the starting powder material, and the powder material is supplied in a flow of this medium into a metering feeder.

[0014] It is desirable that a gas with the temperature $T \leq 300$ K should be used as the gas inert to the powder material.

[0015] The gas-and-powder mixture may be introduced into the core of the accelerating flow from the metering feeder in a pulsed mode.

[0016] When applying the powder material to the surface of an article, the latter may be brought in vibratory motion coaxially to the incident two-phase supersonic flow.

[0017] For enhancing the plasticity of the surface to be coated, the article is subjected to superficial heating.

[0018] In the course of applying a coating, a potential may be supplied to the article to be coated, the sign of this potential being opposite to that of the particles in the two-phase flow of the gas-and-powder mixture.

[0019] The essence of the invention, as regards the herein-proposed device, is that the device for producing coatings from powder materials, comprising a spraying unit made as an accelerating supersonic nozzle with a subsonic converging and a supersonic parts and an intermediate nozzle, a means for feeding a compressed working carrier gas, and a means for introducing a gas-and-powder mixture into the spraying unit, and a metering feeder, is provided with a means for supplying an additional compressed gas inert to the powder material, th intermediate nozzle is made as a supersonic one, with the diameter of the nozzle exit section $d_{sect.}$ smaller than the diameter of the critical section $D_{crit.}$ of the accelerating nozzle, and is arranged coaxially with the possibility of translational displacement in the subsonic converging part, the accelerating supersonic nozzle having at the outlet of the supersonic part a linear portion which passes into a portion with a curvilinear surface of a radius R.

[0020] The device is provided with a unit for treating the powder material with a view to activating and cleaning the surface the particles of the coating material, with a gas pulser connected to the means for introducing the gas-and-powder mixture, with a vibrator for imparting vibrations to the article being coated, and with a power supply source for supplying a potential to the article.

Brief Description of Drawings

[0021] The invention is further explained by a particular example of its embodiment and by th accompanying drawings, in which:

Fig. 1 shows a general view of a device for producing a coating from powder materials;

Fig. 2 shows a spraying unit of the proposed device with a means for introducing a gas-and-air mixture and separating a two-phase flow into fractions.

Best Mode of Carrying the Invention into Effect

[0022] The device of the invention comprises a means 1 for feeding a compressed gas inert to a coating material (to a mixture of powdered components), a shutoff valve 2, a unit 3 for the pretreatment of a powder material to remove an oxide film from and to activate particles of the powder material, a unit 4 for collecting the oxide film and the fine-dispersed fraction of the powder, a unit 5 for feeding the treated powder material to a metering feeder 6, a shutoff valve 7, a pulser 8 of the gas inert to the powder material, a means 9 for feeding a working carrier gas (for instance, air), a system 10 for controlling the working process of applying coatings, a heater 11 of the working carrier gas, a unit 12 for the provision of translational axial displacement of an intermediate supersonic nozzle 13, a chamber 14 for adjusting the carrier-gas flow, a centering perforated sleeve 15, an accelerating nozzle 16 with a linear portion 17 which passes into a portion with a curvilinear surface 18 for varying the direction of motion of the gas flow, a means 19 for turning the gas flow away from the article being coated 20, a means 21 for securing and rotating the article being coated, a unit 22 for the translational displacement of the article being coated, a vibrator 23, a power supply source 24, a tube 25 for feeding the gas-and-powder mixture, a tube 26 for feeding the working carrier gas.

[0023] The method of the invention is carried into effect and the device of the invention operates in the following manner.

[0024] A gas inert to the coating material (to a mixture of powdered components) is fed under a pressure, with the shutoff valve open, from the means 1 to the unit 3 for the pretreatment of the powder coating material, said unit being preliminarily filled with a required amount of a powder (a mixture of powders). When the unit 3 for the pretreatment of the powder material is thrown into action, oxide film is removed from the surface of the powder material particles therein by a mechanical or any other method. After the pretreatment, waste substances in the form of oxide film particles and non-calibrated fine-dispersed fraction of the powder come to the unit 4. Then the particles of the powder coating material are activated by an electromagnetic, thermal, chemical or any other method, depending on the chemical composition and physical properties of the powder material (the mixture of powdered components). The activated particles are supplied with the help of the unit 5 into the m tering fe der 6. After filling the metering feeder 6 with the powder material and with th gas inert to the powder material, the units 3, 4, 5 are switched off, and the shutoff valve 2 is closed, wher by supplying the gas inert to

the powder material is stopped.

[0025] For the process of producing a coating from powder materials, a working carrier gas (for instance, air, nitrogen) is supplied under a pressure from the feeding means 9 to the system 10 for controlling the working process of applying coatings, wherein the pressure is reduced to the required working value. The gas whose pressure reduced to the required value comes to the heater 11 of the gas, where the gas is heated to a temperature corresponding to the rated operating conditions. The heated working carrier gas comes along the tube 26 for feeding the working carrier gas to the chamber 14 for adjusting the carrier-gas flow, and then through profiled apertures in the centering sleeve the working carrier gas is fed to the accelerating supersonic nozzle 16, wherein the carrier gas is accelerated to the velocity required for applying and forming a coating. When the required parameters of the working carrier gas are reached, the shutoff valve 7 is opened, whereby fe ding of the gas inert to the powder material is effected, which gas first comes to the pulser 8, where it acquires a pulsating component having a required frequency. From the pulser 8 the gas inert to the powder material with the required frequency comes to the metering feeder 6 wherein, as the gas under variable pressure is mixed with the particles of the powder coating material, a gas-and-powder mixture is formed, in which the powder particles are in the form of a suspension. The resulting gas-and-powder mixture is fed in the form of a two-phase flow through the tube 25 into the intermediate supersonic nozzle 13 and then into the core of the accelerating flow of the carrier gas into the area of the critical section of the accelerating supersonic nozzle 16. The required rated thermo- and gasdynamic parameters of the working carrier gas and of the pulsating gas-and-powder mixture in the area of the critical section of the accelerating nozzle 16 are attained by displacing the Intermediate supersonic nozzle 13. This displacement is performed in a translatory manner along the axis of the nozzles, with the help of the unit 12 for the provision of translational axial displacement, for a distance depending on the velocity of flow and the frequency of pulsations of the gas-and-powder mixture in the area of the critical section of the accelerating supersonic nozzle 16. When the required displacement is achieved, the unit 12 for the provision of axial displacement of the intermediate supersonic nozzle 13 is switched off. The pulsating mixture of particles with the gas inert to them, issuing from the intermediate supersonic nozzle 13, having the initial axial velocity $0.3 \leq M \leq 1.0$ (where M is the Mach number), is mixed in the area of the critical section of the accelerating supersonic nozzle 16 with the working carrier gas, and in this area the main acceleration of the gas-and-powder mixture takes place. Having acquired th required velocity along the channel of the accelerating supersonic nozzle 16, the flow of the gas-and-powder mixture adjusts the direction of its motion within the linear portion 17, then the main part of the gas flow turns within the portion with a curvilinear surface 18 and gets into the entrance portion of the means 19 for turning off the gas flow. The powder particles of the coating material, having a large mass and sluggishness, continue their rectilinear motion till they collide with the surface of the article being coated. When the necessary thermo- and gas-dynamic conditions for applying the coating are attained, the article 20 to be coated, which is secured in the means 21 for securing the article, is set in (back-and-forth or rotary) motion. Then the vibrator 23, connected with the unit 22 for the displacement of the article, and the power supply source 24, which feeds to the article 20 a potential whose sign is opposite to that of the moving particles, are switched on. This is how the process of applying a coating to and forming a coating on the surface of an article occurs.

[0026] As the gas inert to the powder material, a gas (a mixture of gases) may be chosen, which does not react chemically with the powder material of the coating, for instance, nitrogen, argon, helium, krypton, and others. The choice is determined by particular requirements to the properties of the resulting coating, its structure, and the composition of the material of the latter.

[0027] Removal of the oxide film from the surface of the powder particles of the coating material, activation of the particles, and their preliminary acceleration by the gas inert to the particles, prevent oxidation of the coating material and make it possible, when applying and forming a coating, to obtain chemically pure materials, without oxides in their structure, to improve substantially their structure, physicochemical and technological properties.

[0028] The coefficient of utilization of the coating material being applied, the adhesion, cohesion and its structure depend on the impact velocity of the coating particles being applied with the surface of the material.

[0029] Preliminary acceleration of the particles of the coating material by the gas inert to them at a temperature $T \leq 300$ K, with the velocity of the accelerating gas of $0.3 \leq M \leq 1.0$, and introducing the gas-and-powder mixture into the core of the carrier gas accelerating the particles make it possible to increase substantially the velocity of the particles of the coating material to a velocity close to that of the accelerating gas and thereby to make maximum use of the energy of the gas jet accelerating the particles. Introducing the powder mixture into the core of the accelerating flow of the carrier gas eliminates the effect of deceleration of the particles by the walls of the flow-through part of the supersonic accelerating nozzle, prolongs the service life of the device, increases the coefficient of utilization of the coating material being applied. For eliminating the effect of decelerating the coating particles in the compressed near-wall gas layer, which originates as the supersonic gas jet falls upon the surfac of the article, in the method of the invention the gas flow is turned and moved away from the surface of the article being treated. Turning of th gas flow is brought about by the physical effect which

originates as the plane-parallel flow of gas flows around the curvilinear surface of radius R. Thus, turning of the gas flow and moving it away from the surface of the surface of the article being treated eliminate the appearance of the compressed near-wall gas layer on the surface of the article, and the coating particles continue their rectilinear motion, reach the surface of the article with the velocity which they acquired in their interaction with the gas flow accelerating them. Thereby, it becomes possible, with smaller energy parameters of the gas flow, to apply particles of the of the coating material with higher impact velocities with the surface of the material of the article. As a result, the power inputs are reduced, the coefficient of utilization of the coating material is increased, and the structure, quality and properties of the coating material are improved. Setting the cumulative rate of flow of the working carrier gas and of the gas inert to the powder coating material in accordance with the calculated conditions of the gas flow issue from the accelerating nozzle is the regime in which the pressure in the exit section of the accelerating supersonic nozzle corresponds to the pressure of the ambient medium. Under this condition the velocity of the gas flow issuing from the supersonic nozzle will be maximum. Any changes in the parameters of the carrier gas, such as temperature, pressure, kind of gas, lead to off-design conditions of the issue, i.e., to a loss of the gas flow velocity and, consequently, of the velocity of particles of th coating material being applied.

[0030] Vibratory motions of the article being treated in th case of synchronous introducing in the pulsed mod of the gas-and-powder mixture into the core of the accelerating flow of the carrier gas are effected in such a manner that feeding the gas-and-powder mixture occurs at the moment when the article being treated moves in a direction opposite to that of the flow of particles of the coating material. In this case the velocity of moving particles of the coating material and the velocity of displacing the article being treated are added together. As a result, the velocity of collision of the particles with the surface increases. This leads to an increase in the depth of penetration of the particles into the surface of the material of the article, in the extent of their plastic d formation, in the coefficient of utilization of the coating mat rial, to an improvement in the structure of the coating and its technological properties.

[0031] In order to intensify the course of mechanical and chemical processes in the superficial layer of the material of the article on collision of particles of the coating material with the surface of the article in the method of the invention, the article is subjected to surface heating to a temperature at which the plasticity of the surface of the material of the article is close to the plasticity of the coating material. This makes it possible to apply coatings having a smaller hardness to hard r and less plastic surfaces of articles. In this case the properties of the transition zone (material of the particles and material of the article) change sharply, the structure of this zone and, as a consequence, adhesion of the coating, becomes improved. In the transition zone there is also formed an intermetallic compound on application of a metal to a metal, consisting of the material of the coating particles being applied and of the material of the article. Solid particles, while moving in the gas flow, acquire a charge having a definite value and sign due to friction with gas, against each other, and on the walls of the flow-through part of the gas channel. The value and sign of the charge depend on the material of the particles. When in the method of the invention an opposite sign potential is fed to the surface of the article being coated, there occurs an increase in the velocity of the charged particles as they approach to the surface of the article, and a micro-arc discharge originates on collision.

[0032] Acting on the moving flow of charged particles by different electromagnetic methods and by the value of the potential fed to the article, it is possible to regulate the process of applying and forming the coating.

[0033] This makes it possible to vary the structure, properties and quality of the coating in the course of applying thereof.

[0034] The structural feature of the means for introducing the gas-and-powder mixture make it possible to effect axial introducing of the coating particles with the starting velocity into the core of the working carrier-gas flow accelerating said particles, obviating the interaction of particles of the coating material with the walls of the accelerating nozzle 16 under the conditions of $d_{sect.} \leq D_{crit.}$

[0035] Thereby it becomes possible to prolong the service life of the device, to make maximum use of the energy of the gas flow for increasing the kinetic energy of the particles of the coating material, to carry into effect the process of coating formation with relatively not high starting parameters of the carrier gas, to increase the coefficient of utilization of the material being applied.

[0036] The device of the invention may be used for producing multifunctional coatings and materials from various powdered components selected from the group comprising metals, alloys or mechanical mixtures thereof, as well as dielectrics and organic compounds.

[0037] Owing to the provision of conditions which allow activating the particles and rule out the presence of an oxide film on their surface, the range of materials used for the application of coatings by the method of the invention may be substantially broadened.

[0038] So, the described method and device for producing coatings from powder materials make it possible to intensify the process of applying and forming coatings from various powders and their mixtures, to obtain a coating material without the presence of oxide inclusions in its structure, to improve the structure and physicochemical properti s of the coating material, to increase th coefficient of utilization of the coating mat rial, to reduc the energy parameters of the gas flow, to broaden the possibility of controlling the process of applying and forming coatings, to obtain materials in coat-

ings with unique properties, to broaden the technological and functional possibilities of the process for producing coatings.

Industrial Applicability

[0039] The present invention may be used in metallurgy, mechanical engineering, radio- and electronic engineering and other industries for improving the technological and physicochemical properties of articles, for restoring various worn-out parts, and for imparting specific properties to the surface of articles.

Claims

1. A method of producing a coating from powder materials, comprising the steps of forming an accelerating flow of a working carrier gas, introducing particles of a powder material thereinto, feeding the resulting gas-and-powder mixture into an accelerating supersonic nozzle (16), and applying the powder material to the surface of an article with the help of the gas flow, **characterized in that** before feeding the gas-and-powder mixture into the supersonic nozzle (16), the mixture is subjected to preliminary acceleration by a gas inert to the starting powder material to a velocity defined by the number $0.3 \leq M \leq 1.0$, wherein M is the Mach number, and to additional acceleration by introducing the gas-and-powder mixture into the core of the accelerating flow of the working carrier gas, and in that before applying the powder material to the surface of the article the powder particles are separated from the gas.

2. A method according to claim 1, **characterized in that** forming said accelerating flow of a working carrier gas is effected in accordance with the square law of variation of the profile of the accelerating supersonic nozzle area.

3. A method according to any of claims 1, 2, **characterized in that** feeding the gas-and-powder mixture into the accelerating nozzle (16) is effected with the cumulative flow of the accelerating carrier gas and of the gas inert to the powder material set in accordance with the rated conditions of the accelerating nozzle (16).

4. A method according to any of claims 1-3, **characterized in that** air is used as the working carrier gas and a gas or a mixture of gases which do not react with the powder material is used as the gas inert to the powder material.

5. A method according to any of claims 1-4, **characterized in that** before the preliminary acceleration the powder material is subjected to treatment in a gaseous medium inert to the powder material for activating the powder particles and removing an oxide film from the surface of the powder particles, and in that the powder material is fed in a flow of this medium into a metering feeder (6).

6. A method according to claim 5, **characterized in that** the treatment of the powder material is effected by mechanical, electrochemical or chemical methods.

7. A method according to any of claims 1-6, **characterized in that** the gas inert to the powder material is used at a temperature $T \leq 300$ K.

8. A method according to any of claims 1-7, **characterized in that** introducing the gas-and powder mixture into the core of the accelerating flow of the working carrier gas is effected in a pulsed mode.

9. A method according to any of claims 1-8, **characterized in that** in applying the powder coating material to the surface of an article, the latter is subjected to a vibratory displacement coaxially to an incident two-phase flow.

10. A method according to any of claims 1-9, **characterized in that** in applying the powder coating material a surface heating of the material is effected.

11. A method according to any of claims 1-10, **characterized in that** applying the powder material to the surface to be coated is carried out with feeding a potential to the article, the sign of the potential being opposite to that of the particles of the flow of the gas-and-powder mixture.

12. A device for producing a coating from powder materials, comprising a spraying unit made as an accelerating supersonic nozzle (16) with a subsonic converging part and a supersonic diverging part and an intermediate nozzle (13), a means (9) for feeding compressed working carrier gas, a means for introducing the gas-and-powder mixture into the spraying unit and a metering feeder (6), **characterized in that** it is provided with a means for feeding additional compressed gas, inert to the powder coating material, the intermediate nozzle (13) is made as a supersonic one, with the diameter of the nozzle exit section $d_{sect.}$ smaller than the diameter of the critical section $D_{crit.}$ of the accelerating nozzle, and is arranged coaxially with the possibility of translational displacement in the subsonic converging part, and the accelerating supersonic nozzle (16) has at the outlet of its supersonic part a linear portion (17) which passes into a portion with a curvilinear surface (18) of a radius R.

13. A device according to claim 12, **characterized in that** it is provided with a unit (3) for treating the powder material for activating and cleaning the surface of the particles, which is connected with a means for introducing the gas-and-powder mixture.

14. A device according to any of claims 12-13, **characterized in that** is provided with a pulser (8) connected with the means for introducing the gas-and-powder mixture.

15. A device according to any of claims 12-14, **characterized in that** the pulser (8) is arranged ahead of the metering feeder (6).

16. A device according to any of claims 12-15, **characterized in that** it is provided with a vibrator (23) for imparting vibrations to the article being coated.

17. A device according to any of claims 12-16, **characterized in that** it is provided with a power supply source (24) for feeding a potential to the article.

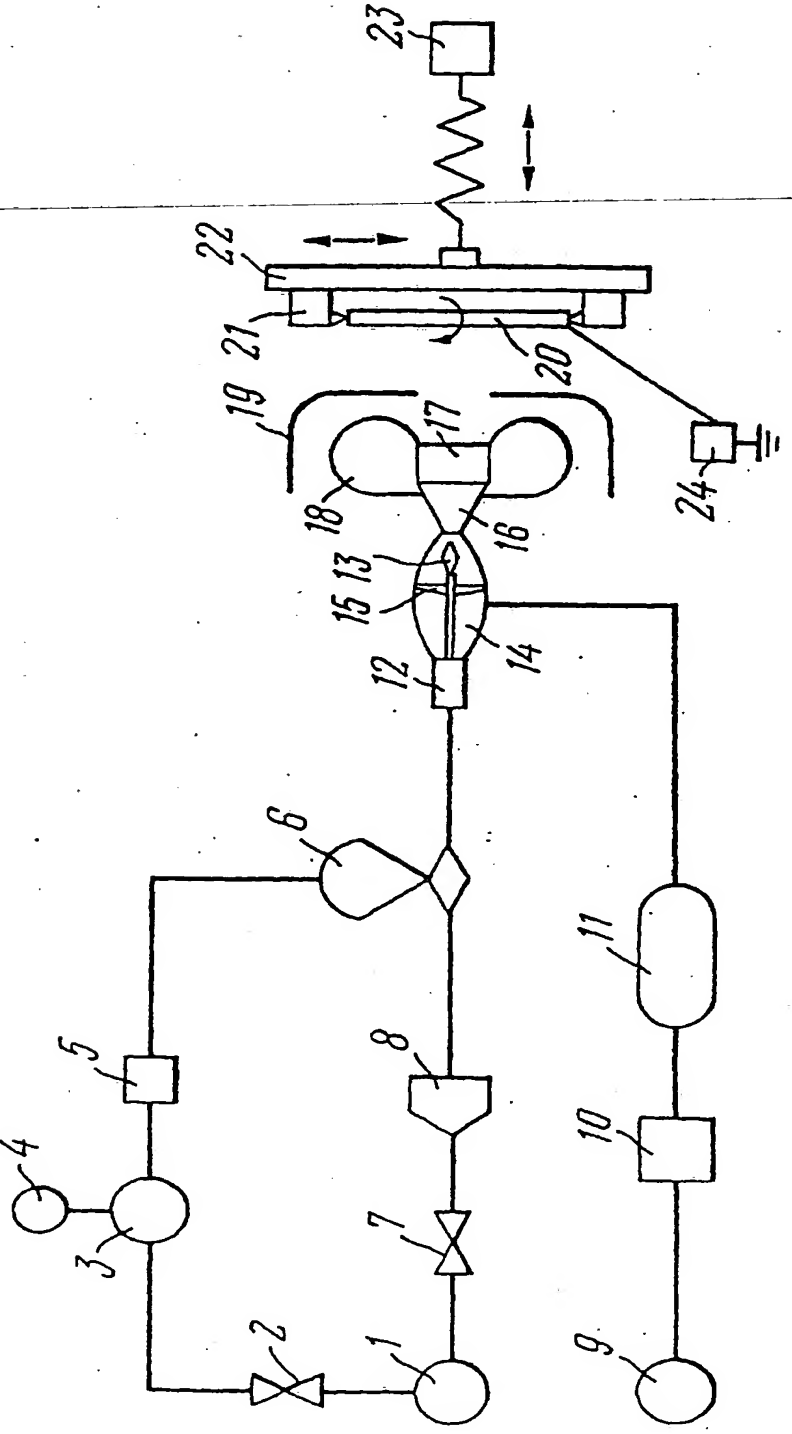

FIG.1